Flow Boiling in Microgap Coolers - an Enabling Technology for 3D Integrated Circuits

Completed Technology Project (2015 - 2018)

Project Introduction

Emerging electronic devices offer unprecedented functionality and efficiency, but their operation is constrained by the remote cooling paradigm. An embedded cooling approach, which facilitates integration of coolant channels within the chip stack or electronics assembly, provides high heat flux cooling, reduces heat exchanger and radiator size, and negates gravity effects on the two-phase coolant flow. The goal of the FY18 effort is to validate the orientation-independent two-phase flow data acquired during ground tests by operating a compact flow loop in microgravity and high-g during a suborbital flight in mid-2018 (flight awarded by the Flight Opportunities Program).

The FY18 study is follow-on to a multi-year Center Innovation Fund (CIF) effort initiated in FY15 with goals of characterizing the thermofluid performance of embedded two-phase microgap coolers (particularly for 3D integrated circuits), assessing the role of gravity on the two-phase coolant flow in such coolers, and developing a map of parameters for achieving gravity-independent performance. The success of the pioneering FY15 study led to follow-on awards in FY16, FY17, and FY18. Collectively, the research program has:
1. Revealed that existing criteria for achieving gravity-independent flow boiling cover several orders of magnitude of channel sizes, particularly for rectangular ducts that are expected in most embedded cooling applications;
2. Demonstrated orientation-independent flow boiling in "chip-scale" channels with heights ranging from 80 to 430 μm (0.003 to 0.017");
3. Dissipated as much as 80 W of heat from a 1.6 cm^2 thermal test chip (50 W/cm^2);
4. Transported 32 W of heat using only 0.9 W of pumping power (COP of 36);
5. Developed a state-of-the-art test facility that supports rapid turnaround testing of microgap coolers (and other innovative evaporators) with a wide range of channel sizes and at differ-ent orientations and flow rates; and
6. Advanced the TRL of microgap flow boiling for space applications from 2 to 4.

Anticipated Benefits

Fundamental Engineering Research focusing on two-phase thermophysics in microgravity environment

This research, if successful, will dramatically reduce testing costs for two-phase systems employing microchannels because flight testing will not be required (i.e., these results will instill confidence that ground-based and flight performance of these systems will be very similar). Furthermore, this research will enable cooling of high heat flux electronic chips and chip stacks (>100W/cm^2) critical to NASA’s onboard processing needs.

This project, if successful, could benefit other government agencies that rely

Flow Regimes

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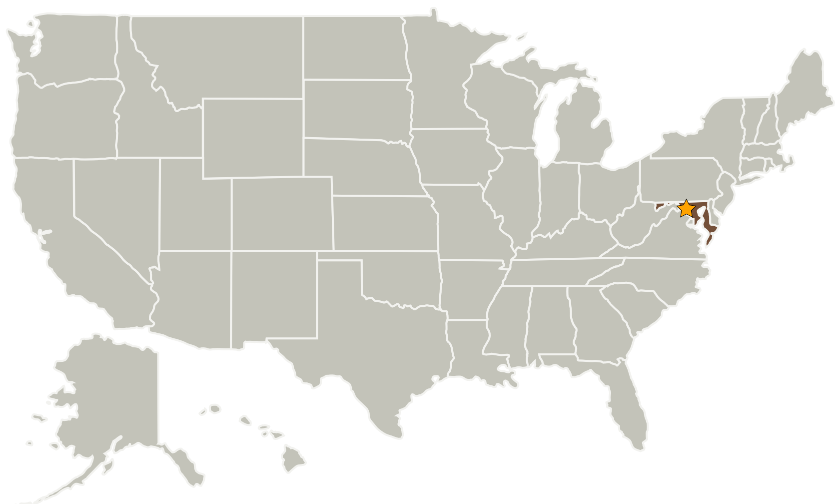
on two-phase cooling systems in reduced gravity (e.g., lunar environment) or hyper gravity environments (e.g., aircraft). High heat flux cooling of electronics (or other power dense devices) in vehicles that maneuver at high acceleration is an area that would benefit greatly from the successful completion of this work as this work could prove that two-phase cooling systems employing microchannel evaporators are relatively insensitive to g-load, thus enabling widespread implementation of this advanced thermal management technique.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Goddard Space Flight Center(GSFC)	Lead Organization	NASA Center	Greenbelt, Maryland

Primary U.S. Work Locations
Maryland

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Goddard Space Flight Center (GSFC)

Responsible Program:

Center Innovation Fund: GSFC CIF

Project Management

Program Director:

Michael R Lapointe

Program Manager:

Peter M Hughes

Project Managers:

Charles D Butler
Michael A Johnson

Principal Investigator:

Franklin L Robinson

Center Innovation Fund: GSFC CIF

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Images

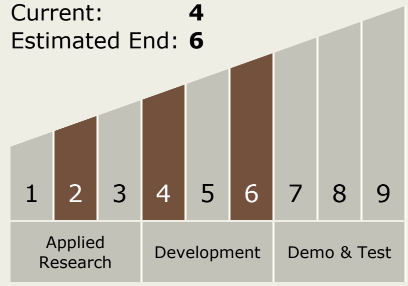
Two-phase Flow in a Microgap Cooler
Flow Regimes
(https://techport.nasa.gov/image/20763)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Maturity (TRL)

Start: **2**
Current: **4**
Estimated End: **6**



Technology Areas

Primary:

- TX14 Thermal Management Systems
  └ TX14.2 Thermal Control Components and Systems
    └ TX14.2.2 Heat Transport

Target Destination

Foundational Knowledge